GOATS'2000
Adaptive Detection, Tracking and Interrogation of VSW Seabed Targets

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LONG-TERM GOAL

Develop environmentally adaptive sonar concepts for autonomous underwater vehicle networks for detection and classification of proud and buried targets in very shallow water.

OBJECTIVES

The objective of this sub-project is to develop adaptive responses of underwater vehicles acting as bistatic sonar platforms, including real-time, autonomous beamforming, detection and tracking algorithms, and adaptively modify the platform motion to optimally characterize the 3-D acoustic scattering by detected seabed targets.

APPROACH

The center piece of the research effort is the GOATS'2000 Joint Research Program (JRP) conducted by SACLANTCEN and MIT with ONR support. Building on the experience of the highly succesful GOATS'98 pilot experiment (Schmidt *etal.*, 1998), the JRP combines a series of experiments, with the two major ones being planned for 2000 and 2002, and modeling and simulation work to explore the potential of autonomous underwater vehicle networks as platforms for new sonar concepts exploring the full 3-D acoustic environment of VSW. The GOATS'2000 experiment will incorporate 3-4 AUV's, two of which will be operated by MIT, one equipped with a subbottom profiler, and one equipped with an 8-element acoustic array, an autonomous acquisition system and an acoustic source for monostatic measurements. The first vehicle will be used as a rapid environmental assesment platform and as a bi-static source platform, which together with fixed parametric source capabilities will be used to insonify the seabed. The second AUV will be used for sampling the 3-D acoustic field either using fixed or adaptive survey patterns, and as a testbed for adaptive response to target detection. The modeling effort is centered around the new OASES-3D capability developed at MIT under a sub-project funded by code 321OA (Lee 1999, Schmidt and Lee 1999). OASES-3D provides wave-theory modeling of the full 3-D acoustic environment associated with mono- and bi-static configurations in VSW with aspect-dependent targets and reverberation features.

WORK COMPLETED

Figure 1. (a)GOATS'2000 range in Biodola Bay, Elba, with TOPAS parametric projector and bottom mounted targets and natural seabed ripple fields. (b) Deployment of Oddysse bistatic receiver AUV from RV Alliance, Sep. 25, 2000.

The most significant component of the FY00 has been associated with the planning, preparation and initiation of the GOATS'2000 experiment in Golfo di Procchio, Elba Island, being carried out as a Joiunt Research Project (JRP) with SACLANT Undersea Research Centre in the period Sep. 18 – Oc. 14, 2000. The experiment collects a variety of ocenographic and navy resources for performing rapid environmental assesment (REA) and mine countermeasures (MCM) in shallow (SW) and very shallow water (VSW). A fleet of 4 AUV's are operated from R/V Alliance. One is equipped with an 8-element acoustic array in a 'swordfish' configuration serving as bistatic receiver for measuring the 3-D scattering from natural ripple fields and aspect dependent targets deployed on and within the seabed. The seabed is insonified by a TOPAS parametric source on a stationary tower, and in dual-AUV missions by an Edgetech subbottom profiler mounted on a second MIT Odyssey II AUV. This vehicle will also be used for bottom characterization during then REA component of the experiment.

A third AUV, an FAU Ocean Explorer is equipped with a sidescan system for seabed mapping and multiaspect target classification.

Finally, a Taipan AUV is operated by a group from LIRMM in France, collecting CTD data in Procchio Bay. This data is assimilated into a nested ocean forecasting framework together with CTD, XCTD, and XBT data collected by R/V Alliance during nightime operations.

RESULTS

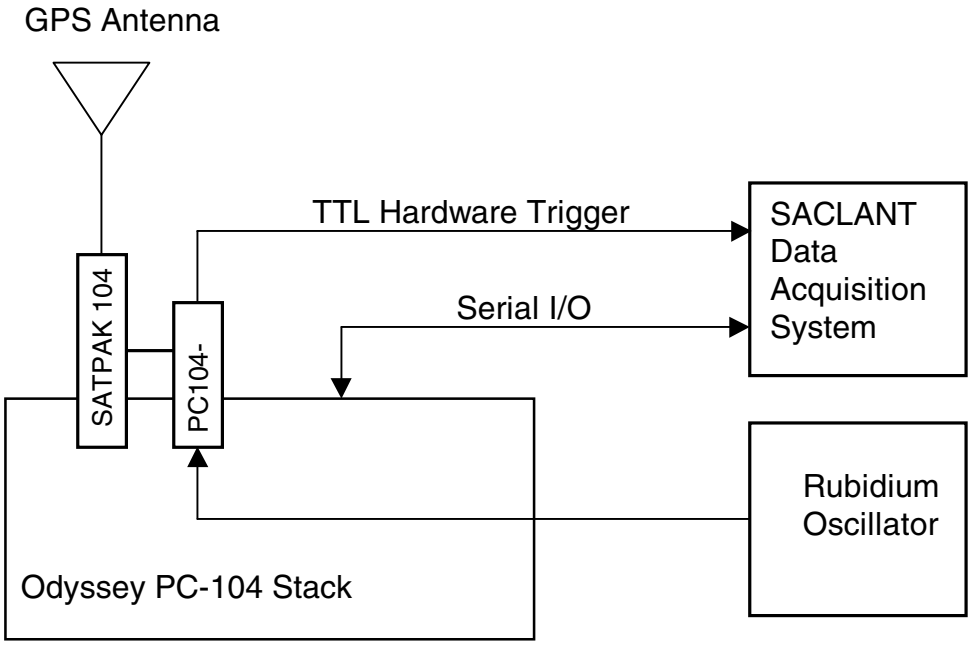

Figure 2. MIT Multi-AUV Time Synchronization System

A number of major improvements of the Odyssey II vehicles and their acoustic configuration has been achieved under this project, in addition to major reconfigurations of the vehicles carried out under the general ONR AOSN effort, finishing this year.

First of all, GOATS'98 revealed a need to improve the time synchronization of the acoustic sources and the bistatic AUV receiving platforms. MIT has therefore developed a new Multi-Vehicle Precision Time Synchronization with the capability of synchronizing the Odyssey time base to within 500 nanoseconds of UTC via GPS. While on the surface, all vehicle and ship/shore stations are synchronized with each other to within 1 microsecond of UTC. During dives the clock drift on Odyssey vehicle has been reduced to less than 1 microsecond/hour using a rubidium oscillator.

Another need identified in the GOATS'98 experiment was a capability to externally trigger the SACLANT data acquisition system on the Odyssey AUV. The approach developed allows for extremely accurate (< microsecond) recording of acoustic travel times, enhancing processing performance substantially compared to the earlier experiment.

To allow for coordinated AUV operations needed for bistatic configurations, MIT has developed together with the acoustic communication group at Woods Hole a capability to transmit real-time telemetry to and from multiple operating Odyssey vehicles and ship/shore stations, and between vehicles.

This development is critical to adaptive cooperation between multiple operating Odyssey vehicles, which will be partially demonstrated in GOATS'2000.

Finally, GOATS'98 revealed a need for improved LBL navigation for performing coherent synthetic aperture processing. Enhanced navigation has been achieved by integrating a new Kalman filter-based long-baseline (LBL) navigation algorithm into the Odyssey vehicle. This was achieved in collaboration with J. vaganay at LIRMM, France.

IMPACT/APPLICATION

The long-term impact of this effort is the development of new sonar concepts for VSW MCM, which take optimum advantage of the mobility, autonomy and adaptiveness of the AOSN. For example, bi- and multi-static, low-frequency sonar configurations are being explored for buried mines in VSW, with the traditional high-resolution acoustic imaging being replaced by a 3-D acoustic field characterization as a combined detection and classification paradigm, exploring spatial and temporal characteristics which uniquely define the target and the reverberation environment.

TRANSITIONS

The GOATS AUV effort has been and is conducted by the MIT Sea Grant AUV Laboratory, in part funded by this project and the AOSN MURI. A new AUV enterprice, Bluefin Robotics, is a spin-off from the MIT Laboratory, and is currently developing a new Odyyssey III Battlefield Preparation AUV for ONR, building in part of experience from the GOATS`98 experiment (Schmidt *etal.*, 1998)

The 3-D acoustic models for VSW MCM environments developed under GOATS are being integrated in a multi-AUV simulation capability developed by the MIT Sea Grant AUV Laboratory and Bluefin Robotics under the ONR project (Code 321TS) "Sensor and Operational Tradeoffs for Multiple AUV MCM" (N00014-99-1-0851). Also, the simulation capability is being utilized and augmented under the ONR SBIR (code 321OE) "USBL Positioning of Littoral Swarm Systems" (N00014-97-C-0288) in collaboraion with IS Robotics.

RELATED PROJECTS

This effort is part of the US component of the GOATS`2000 Joint Research Project (JRP) with the SACLANT Undersea Research Centre. The MIT GOATS effort is funded by ONR codes 321OA (Simmen), 321OE (Swean), 321TS (Jacobson), and 322OM (Curtin).

The GOATS effort is strongly related to the ONR Autonomous Ocean Sampling Network (AOSN) initiative. Thus the GOATS'98 experimental effort was funded in part by the AOSN MURI, (PI: J. Bellingham). In terms of the fundamental seabed penetration physics there are strong relations to the High-Frequency Bottom Penetration DRI (PI: E. Thorsos). This effort also builds on acoustic modeling efforts initiated under the Sea-Ice Mechanics Initiative (SIMI), and continued under funding from ONR code 321OA (Simmen).

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